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Co/Pd Multilayer Based Recording Layers For Perpendicular Media

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ABSTRACT

The results of the experimental study of CoX/Pd multilayer based recording layers for perpendicular recording media are presented. The perpendicular magnetic recording media with multilayer recording layers and high moment soft underlayers were deposited by magnetron sputtering. It is shown how a favorable microstructure of the multilayer films can be achieved by the use of the appropriate buffer layers. The effects of boron addition to the cobalt layer in a multilayer recording layer is described. The feasibility of the aging process that leads to the reduced exchange coupling in the multilayer recording layer, is demonstrated. It is shown that boron addition to the cobalt layer accelerates the aging process.

INTRODUCTION

As the storage industry ramps the areal bit densities at increasingly higher rates, thermal instabilities in recording media begin to manifest themselves[1]. Perpendicular recording technology[2] while being technically close to conventional longitudinal recording and the least difficult technology to make the transition to if necessary[3, 4, 5, 6], addresses the issue of thermal stability for areal bit densities exceeding 100Gbit/in² [7].

Several candidates for the perpendicular media recording layers are being considered. Hexagonal single layer CoCr-based alloys are among the strongest candidates due to a wealth of knowledge about material properties accumulated over the years using these alloys for longitudinal media. The major drawback in using hcp Co alloys is the difficulty in achieving the high remanent squareness, preferably equal to one. Remanent squareness of less than one leads to substantial DC noise and potential thermal instabilities. L10 phases of CoPt, FePt, etc. suffer from the lack of knowledge of how to control the microstructure and magnetic properties. These highly attractive materials due to their high magnetic anisotropy can play an important role in the future magnetic recording technologies if the mentioned above technical difficulties are resolved.

An alternative approach is to use Co and Co-alloy based multilayers[8, 9, 10]. In this set of materials, the magnetic anisotropy is controlled by interfacial effects between Co and Pt or

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Pd non-magnetic (but highly polarizable) spacer layers. The multilayers form an attractive class of materials since they exhibit high remanent squareness and easily controlled magnetic anisotropy with both aspects being critical for the thermal stability.

EXPERIMENTAL DETAILS

The media films were deposited by magnetron sputtering onto AlMg/NiP substrates at room temperature. The following general perpendicular media structure was utilized [substrate/buffer/soft underlayer/buffer/multilayer/overcoat]. $\text{Ni}_{45}\text{Fe}_{55}/\text{Ta}/\text{FeAlN}$ was used as a soft underlayer. Indium oxide doped with 10 wt% of tin oxide (ITO) was used as a seed/buffer layer to control the microstructure of the $(\text{CoX}/\text{Pd})_N$ multilayer recording layer[8]. Tantalum was used as a buffer for Co/Pd multilayer films as well for comparison. Both pure Co and Co doped with 4% of boron were used in a multilayer structure. The multilayer films were deposited in 30mTorr of Kr. A 5nm hydrogenated carbon (C:H_x) overcoat was used as a protective wear-resistive layer.

Single pole recording heads with the pole tip made of $\text{Ni}_{45}\text{Fe}_{55}$ alloy with a $4\pi M_S$ of 16kG and GMR based readers were used to test the media. The track width was $0.8\mu\text{m}$. Autocorrelation signal-to-noise (ACSN) ratio using a pseudo-random bit pattern covering spectral density from 0 to 200kfc was used as a signal-to-noise ratio (SNR) measurement technique.

A custom built polar Kerr magnetometer was used to measure the M-H loops. The structure of the films was determined using a Philips X-Pert Pro X-ray diffractometer and transmission electron microscopy (TEM)[11]. The compositional distribution of the films was studied by electron energy loss spectroscopy (EELS).

INFLUENCE OF ITO BUFFER LAYER ON THE MICROSTRUCTURE AND ON THE MAGNETICS OF MULTILAYER FILMS

It is important to emphasize the role of ITO buffer layers on the microstructure and resulting magnetic properties of multilayer films. Figure 1 compares plain-view TEM micrographs of the multilayer films deposited on Ta and ITO seed layers. The morphologies of the two films are distinctly different. In the case of the Ta buffer layer, a usual polycrystalline granular structure is observed while in the case of the ITO buffer layer, the films appear to consist of agglomerates of grains that are surrounded by either different density or different elemental composition material. EELS revealed that the intergranular material is a CoPd alloy with substantially lesser density than the material that makes the body of the columns/grains.

The cross-sectional TEM micrograph shown in Fig. 2 compares the Co/Pd multilayer films grown on ITO and Ta buffer layers. The Co/Pd multilayer on ITO buffer exhibits two clearly distinct layers: a continuous film to about 1/4 of the film thickness followed a film represented by columns, or grain agglomerates, surrounded by lower density material regions. In contrast, the Co/Pd multilayer films grown on Ta buffer layer appears to have a continuous structure.

One can expect that the double-layer structure of the multilayer films would have a strong influence on the magnetic properties of the films and, ultimately, on the recording

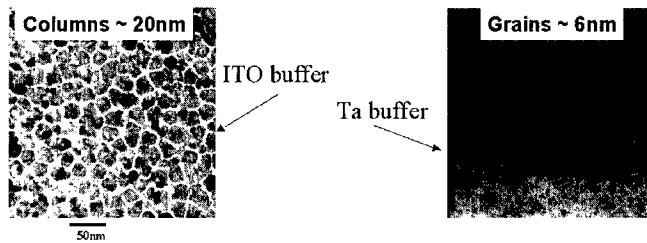


Figure 1: Bright field plain-view TEM images of Co/Pd multilayer films on Ta and ITO buffer layers.

performance of the media that utilizes such multilayers as recording layers. The distinctly different microstructures of the two layers will result in different magnetic properties of the two layers. Reduced exchange coupling is expected between the columns which are surrounded by lower density material while the bottom continuous layer is expected to be strongly exchange coupled within the layer.

Figure 3 compares M-H loops of multilayer films grown on Ta and ITO buffer layers. In the case of a Co/Pd multilayer film deposited on a Ta buffer layer, the film is continuous and can be expected to be substantially exchange coupled. This strong exchange in the multilayer film grown on a Ta buffer is demonstrated in Fig.3 where mostly collective magnetization reversal takes place at essentially the same external field value (very high value of the slope in the reversal region). In the case of a Co/Pd multilayer film deposited on a ITO buffer layer where 3/4 of the film consists of exchange decoupled magnetic columns, the shape of the hysteresis loop is dramatically different, with a clearly finite slope of the magnetization reversal region and a drastically boosted coercivity value.

It is commonly believed that in multilayers the magnetic anisotropy is controlled by the interfacial effects between the layers and for that reason is called surface anisotropy. No significant crystalline texture was observed using X-ray diffraction in Co/Pd multilayer films grown on a ITO buffer, which further supports the view that the anisotropy arises predominantly from interfacial effects in the multilayer films (See Fig. 4.) This is in contradiction to previously published data where authors correlated the presence of $<111>$ crystallographic texture in Co/Pd multilayers with the increase of magnetic anisotropy[12].

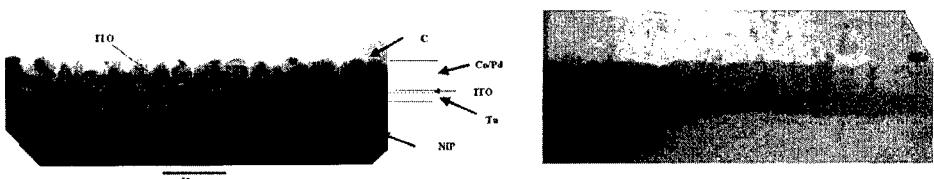


Figure 2: Cross-section TEM image of Co/Pd multilayer film on ITO buffer layer (left) and on Co/Pd multilayer film on Ta (right).

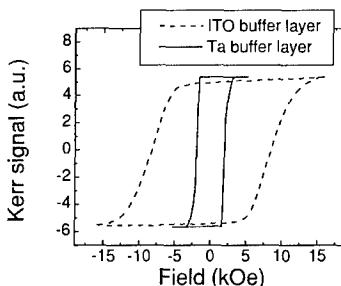


Figure 3: M-H loops for the multilayer films grown in ITO and Ta buffer layers.

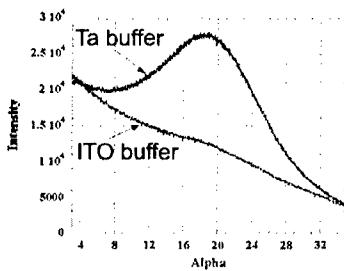


Figure 4: X-ray (111) rocking curves for Co/Pd multilayers grown on Ta and ITO buffer layers.

To further illustrate the importance of the correct microstructure of the multilayer films that the ITO buffer layer provides, the recording performance of the two multilayer based media (with Ta and ITO buffer layers) were studied. Figure 5 compares roll-off curves and SNR of the two media. A substantial improvement of the recording performance of the media with the ITO buffer layer is observed vs. media in which Ta is used as a buffer layer for the Co/Pd multilayer recording layer.

EFFECTS OF BORON ADDITION TO COBALT LAYER

Figure 6 compares roll-off curves and SNR of Co/Pd and CoB/Pd multilayer based perpendicular media. A clear improvement in both SNR and roll-off curves is observed with the boron addition. TEM studies of the multilayer microstructure did not reveal any measurable variation in the column size distribution leading to the conclusion that the most likely role of boron is of an additive facilitating better exchange decoupling of the magnetic columns.

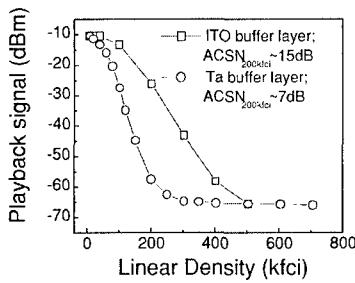


Figure 5: Roll-off curves and SNR for the media with ITO and Ta buffer layers for Co/Pd multilayer structure.

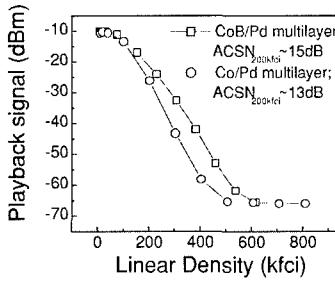


Figure 6: The effect of boron addition to the Co layer in the Co/Pd multilayer recording layer.

AGING EFFECTS

The recording performance of as deposited films was compared to the recording performance of the films exposed to ambient conditions for 180 days. As shown in Fig. 7 which compares the two sets of data, improved SNR and roll-off curves that extended to higher linear densities were observed in the "aged" films. One of the likely explanations of the observed improvement in the recording performance is preferential oxidation of the column boundaries as the lower density material in the grain boundaries facilitates oxygen and/or water vapor diffusion. Since no measurable aging effect was observed in Co/Pd multilayers without boron additions, one can conclude that boron additions act as a precursor for accelerated column boundary oxidation. Although 180 day aging is clearly not a manufacturable process, the observed aging phenomenon suggests feasible routes for improving the multilayer media performance via accelerated aging techniques such as aging in an oxygen rich environment at elevated temperatures.

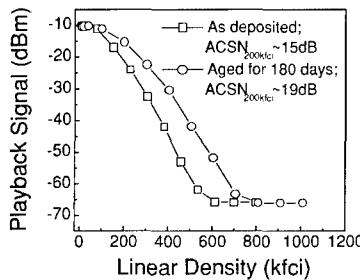


Figure 7: The Influence of the aging process on the recording performance of the multilayer based media.

SUMMARY

In summary, the effects of an ITO buffer on microstructure and magnetic properties of Co/Pd multilayer films has been studied. It was shown that boron additions improve the recording performance of Co/Pd multilayer based media. Furthermore, it is shown that boron works as a precursor in the aging of the CoB/Pd multilayer structures, helping to further improve the recording performance of multilayer based media.

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